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Study on activation and improvement of crop seeds by the application of plasma treating seeds equipment

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ABSTRACT

Plasma technology is applied in various fields, which involves in stimulating the germinability and amelioration of crop seeds, increasing crop production and displaying high quality, stress tolerance and other beneficial traits. Crucial techniques of plasma treating seeds (PTS) are introduced and the technical applications of activating seeds with key parameters of plasma discharge equipment are discussed. With a lot of laboratory researches and field tests, the biological effects of non-thermal PTS are analyzed. Meanwhile, a preliminary discussion about the PTS mechanism and technical popularization is made. Main findings including non-thermal plasma treatment are as follows: (i) the germination rates of the maize seeds were 72% or so if treated by 140 W–160 W power, which was the highest; (ii) the length of the wheat radicle and germ was increased effectively by 8.7 cm and 3.3 cm, and the dry weight of the wheat was increased by 10.1%; (iii) the germinative energy and germinating percentage of the aging seeds could be greatly increased. It is concluded that PTS enhances seed germination as well as plant growth, meanwhile, more crops are yielded and the quality is improved. Both technologies and plasma discharge equipment have significant applicative value and popularize in agriculture.

1. Introduction

Plasma is the fourth state of matter and it can be subdivided into high temperature plasma or hot plasma (thermal plasma) and low temperature plasma or cold plasma (non-thermal plasma). In laboratory, plasma is created by low pressure discharge where the electrons have the temperature of 1–10 eV(1 eV = 11,600 K) while ions have only several hundred Ks which equals the temperature of neutral particles. This kind of ions is called plasma and it has practical value, because its macroscopical temperature is similar to the inhouse temperature.

Using plasma to modify the material surface and activate crop seeds has caused widespread concern [1–3]. In international communities, plasma activation of crops is the newest developed technology. It was used to increase the crops production and also applied to the principles of physics science, the fields of biology and agriculture [4–6]. This technology originated from space science experiment, where crop seeds carried into different vigor in the demonstrated space. Based on this result, Institute of Applied Physics, Russian Academy of Sciences, is the first one who has succeeded in developing plasma treating seeds (PTS). PTS simulates ionosphere state in space to expose seeds to gas ions (plasma), rays, magnetic fields, vacuum and other materials, whose joint action activates physiological activities of seeds and their potential anti-stress gene expression. According to their report, satisfying results were produced including improved crop vigor, drought resistance, cold resistance and other stress resistance.

It has been widely accepted that more and more attention has been given to the R & D of PTS [7–10]. In Russia, PTS technologies have become commercialized and have been put into production. In China, the plasma devices and equipment for modification and treatment of seeds are imported by some government departments, enterprises and institutions. However, some deficiencies in the equipment such as high energy consumption and bad technical repeatability are identified. After a careful study and thorough investigation, the fundamental deficiencies in the imported equipment are that the problems with discharge technology don't be solved well. Precisely, a large amount of direct current (DR) discharge phenomenon is observed in radio frequency (RF) electric field. The primary causes lie in the fact that the effective power in RF electric field is very small and the requirements for the technical repeatability are not completely satisfied. Because the DC potential is produced in the RF alternative electric field (13.56 MHz) where electrodes are asymmetric, at the same time, the metal barrel/tube involves in the grounding electrode discharging electricity to the electrode target, and then a large amount of charge cannot be released. In some parts of China, the technology of glow discharge area is used to treat seeds, which is formed by connecting RF source to two sheets of

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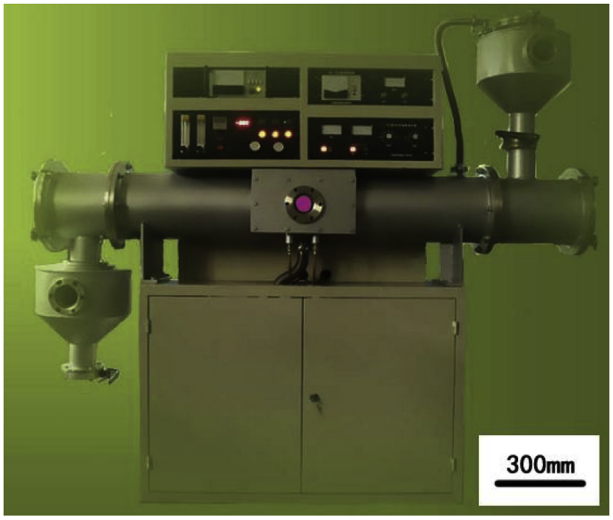


Fig. 1. Plasma treating seeds (PTS) equipment.

parallel electrode plates. The problems with this treatment are that glow discharge would emerge between the two electrode plates and the inner wall of the cavity, which results in a sharp increase in power dissipation and waste of energy. Plasma crucial techniques on the surface modification of seeds depend on the design of discharge electrodes and the determination of parameters related to them [11,12].

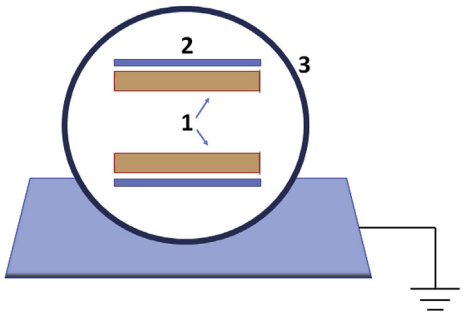
In the following sections, the effects on the modification of all kinds of crops of the plasma treating seeds (PTS) equipment are examined and investigated under both laboratory and field cultivation. Relevant experiment processes are introduced and the PTS mechanism and popularization of PTS techniques are also discussed.

2. Experimental details

2.1. Equipment

Plasma treating seeds (PTS) equipment fills the domestic gap in China. It is considered as the most advanced and newest one. PTS has been developed by referring to Russian plasma technologies (Fig. 1). PTS equipment mainly comprises four systems: the FR matching box, vacuum system, plasma generator and the drive system. Its components include a high frequency discharger, a vacuum chamber, a vacuum pumping system, a feeding hopper and an outlet hopper.

The key to plasma seed treatment is electromagnetic shielding and suspension electrode technology, which is showed in Fig. 2. The working process is that the high frequency discharger produces plasma. Seeds are spread out flatly on the drive belt from the feeding hopper, which are transmitted through the treatment area and unloaded from the outlet hopper. The time of treating and processing seeds can be



1. counter electrode ; 2. plate metals; 3. Ground shell

Fig. 2. Electromagnetic shielding and suspension electrode technology.

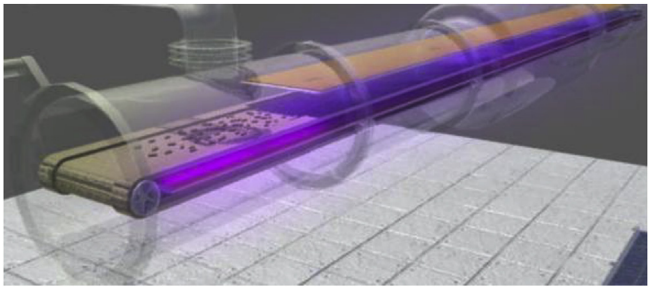


Fig. 3. Diagram of plasma discharge (glow discharge with RF plasma).

controlled by regulating the running speed of the drive belt. Main technical parameters are as follows: (i) when the RF glow discharge technology is available, the power supply is Type SY crystal-controlled RF power source with frequency of 13.56 MHz and the output power from 50 to 1000 W which can be adjusted continuously; (ii) the vacuum system consists of a vacuum chamber (equipped with a built-in drive belt), a four-way pump group and a four-way vent system. The volume of the working vacuum chamber is 260 mm by 1200 mm. The diagram of the discharge effect of the air in the reaction chamber of treating seeds is presented in Fig. 3. The state of bright and uniform violet smoke can be observed in the discharge area.

2.2. Materials needed

The test materials were maize, peppers, wheat, soybeans, tomatoes, eggplants, pumpkins, and so on. Those seeds were prepared by screening, and then need drying. After the plasma modification, the purity of working gas was more than 99.996%.

2.3. Experimental methods

The plasma processor used in this experiment is a capacitive coupled glow discharge [13–15]. First, the seeds were positioned in the discharge space by the running transmission device at a specific speed. Second, the vacuum pump was started, and the background vacuum reached to 1 Pa. The working gas (Air or Air + He mixture) was let in at a certain flow rate controlled and monitored by a rotary flow meter. Third, the air pressure was obtained when needed and keeped constant. The discharge power was regulated, and at the same time the reflected power was minimized. Finally, when reaching the processing time, the power was turned off and the area was inflated meanwhile the seeds were removed.

The technical parameters determined the tuning range of doses. Different RF power could process with the power of 50–1000 W (Watts), with the time of 5–90 S (Second) and the vacuum level of 30–200 Pa (Pascal). Different RF power was used to treat crop seeds and a variety of trials were conducted with the control group (CK), such as laboratory germination tests and field plot experiments. Laboratory tests included testing the germination percentage of old seeds with sufficient water and also with under water stress to find out the differences of germination energy and rate. After the best technical process parameters was determined in the lab tests, field test was carried out to compare the effects of different treating doses on enhancing yield, drought resistance, disease resistance and so on.

2.4. Active enzyme tests

The activities of the following enzymes were tested in the experiment: amylase (ATP), peroxidase (POD), and superoxide dismutase (SOD), which play a significant role in the growth of crops. The experiments were performed by using certain kind of seeds. Cultivated crop seeds were in two dishes and were treated with plasma and